COMMERCIAL TECHNOLOGIES FROM THE W-100 PROGRAM

Vincent C. Truscello, Jack F. Mondt, Toshio Fujita

S1'-100 Project
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
(818) 354-1820, (818) 354-1900, (818) 354-8700

Abstract

For more than a decade, the Jet Propulsion Laboratory (JPL) and Los Alamos National Laboratory (LANL) have managed a mul t i -agency fo nded effort to devel op a space. reactor power system. This SP-100 Program has developed technologies required for space power systems that can be implemented in the industrial and commercial sectors to i reprove our compel it iveness in the global economy. Initial steps taken to transfer this technology from the laboratories to industrial and commercial entities within the United States include: 1) identifying specific technologies having commercial potential, 2) distributing information describing the identified technologies and interacting with interested commercial and industrial entities to develop application-specific details and requirements, and 3) providing a technological data base that leads to transfer of technology or the forming of teaming arrangements to accomplish the transfer by tailoring the technology to meet application-specific requirements.

S1'-100 technologies having commercial potential encompass fabrication processes, devices, and components, Examples are a process for bonding refractory metals to graphite, a device to sense the position of an actuator and a component to enable rotating machines to operate without supplying lubrication (a self-lubricating ball bearing). Shortly after the NASA Regional Technology Transfer Centers widely disseminated information covering SP-100 technologies, over one hundred expressions of interest were received. These early responses indicate. that there is a large potential benefit in transferring SP-1 00 technology. interactions with industrial and commercial entities have identified a substantial need for creating teaming arrangements involving the interested entity and personnel from laboratories and their contractors, who have the. knowledge and ability to tailor the technology to meet application-speci fic requ i rements.

INTRODUCTION

The S1'-100 Program recently completed the development of technologies for space reactor power systems (see references 1-6). The effort, which was carried out from 1983 to 1994, was jointly supported by the Department of Energy (DOE), the National Aeronautics and Space Administrat ion (NASA), and the Ballistic Missile Defense Organization (BMDO), that was formerly named the Strategic Defense Initiative Office (SDIO). 'l'he technology development activities were directed and managed by a Jet Propulsion Laboratory (JPL) and Los Alamos National Laboratory (LANL) Project Office, and developed by a team of contractors and national laboratories led by Martin Marietta Corporation (MMC).

The technologies developed for the S1'- 100 Space Reactor Power System (SRPS) arc available for implementation when required for future commercial, NASA and military space missions. Very importantly, many of the individual technologies are applicable to multiple uses in the industrial and commercial sectors. In concert with the national effort to improve our competitive posture by transferring government developed technologies to our industrial and commercial sectors, JPL, together with other laboratory and contractor personnel familiar with SP- 100 technologies, is undert aking an effort focused specificall y on t ran sferri ng t hcsc technologies. This effort is supported by the Commercial Program Office at JPL that includes the "J'ethnology Affiliates Program, intellectual Property Management, and Technical Informat ion Dissemination.

This paper describes the SP- 100 technology transfer effort in terms of its overall strategic plan, steps initiated as of July, 1994, and the resulting progress. Conclusions are drawn regarding the potential benefits that can be achieved and the scope of the activity needed to successfully capture. the full benefits of transferring SP-100 technologies.

SP-100 TECHNOLOGY TRANSFER EFFORT

As depicted in Figure 1; the overall S1'-100 technology transfer effort consists of four basic phases. The actions required for the. accomplishment of these phases are to 1) identify and de.scribe the S1'- 100 technologies, 2) distribute SP-1OO technology information to industrial U.S. companies, 3) establish how the needs of the user can be met by this technology, and 4) implement technology transfer.

The first phase requires a systemat ic review of the technology development activit ies uncler-taken within the SP- 100 Program. Each of the. individual technologies are assessed in terms of their potential for being used to improve commercial products. Those S}'- 100 technologies judged to have the highest commercial potential are selected. Informat ion that describes these technologies and their identified potential commercial appl icat ion is then prepared.

In the. second phase, this information is distributed to a network of NASA Technology Transfer Center-s and is provided also directly to U.S. industrial and commercial companies involved with the identified potential applications. During the third phase, specific needs of the commercial user are identified, and ways in which the S1'- 100 technology can meet these needs are established.

The fourth phase uses the specific knowledge obtained in the third phase as the basis for implementing the transfer of technology. In some cases, simply providing the. SP-100 technology data base to a potential user is sufficient to accomplish the transfer of technology. For these cases, the technology is either directly applicable or the interested company has the knowledge, ability, and resources to tailor the technology to meet his needs. In other cases, teaming arrangements must be implemented and resources provided to support the interested industrial or commercial company in modifying the technology to meet the requirements of their application. Technical support can be provided by S}'-100 component suppliers or laboratory personnel who are familiar with the technology and possess the expertise required for the tailoring effort. Resources are provided by the government to match industry funds, as required, to modify the technology.

DESCRIPTION OF SP-100 TECHNOLOGIES

Following a systematic review and assessment of the technologies developed in the SP- 100 Program, a set of technologies judged to have high potential for commercialization was selected. 'l'he selected SP-100 technologies are cat egori zed as processes, devi ces, and components.

The process technologies, along with their identified commercial possibilities, are listed in Table 1. Bonding techniques which join different materials and have low electrical and thermal resistance have a wide range of applications. Explosive forming is used to mechanically join dissimilar materials. 1 lard surface coatings that remain bonded to the substrate material have many applications.

Table 2 covers device technologies and their potential commercial application. The device category contains a collection of very different devices. The devices include heat exchangers and heat pipes for heat transfer, themoelectrics for power conversion and cooling, electrical actuators for moving control segments, sensors for measuring position and temperature, and gas/liquid separators for both microgravity and gravity applications.

The third category, SP-100 component technology, is presented in Table 3. This category consists of a wide range of components having, broad commercial possibilities. The new technology components are carbon-carbon tubes for heat exchangers, compliant pads for joining materials having, different coefficients of thermal expansion, high temperature coils for motors, pressure transducer adaptations for use with high-temperature and/or corrosive fluids, self-lubricating ball bearings for rotary equipment at high temperatures, and very high temperature metal-ceramic electrical insulators to isolate high temperature, high-voltage environments.

INFORMATION DISSEMINATION

Working closely with NASA Regional Technology Transfer Centers (RTTCs), the SP-100 technology transfer project has successfully disseminated information to industry covering the selected technologies available from the S1'-100 program. Over 2.000 companies have been sent data sheets describing the technologies and suggesting potential commercial applications. 'l'he RTTCs have also placed notices within their regularly published newsletters describing the technologies available and directing interested companies to JPL. Other sources of public notice have included BMDO's publicat ion, "*The Update*", the NASA publication, "*Innovation*", and a private. sector newsletter called, "*Advanced Manufacturing Technology*".

INTERACTIONS WITH POTENTIAL USERS

As of July, 1994, more than 135 companies have indicated an interest in one or more of the selected S}'-lOO technologies. Each of these companies was contacted. in general, this contact led to providing thcm with detailed reports covering, the technology and a series of follow-on discussions that clarified the application and defined specific steps that would be required to implement the. technology. In some cases, SP- 100 contractors involved in the development were brought into the discussion to clarify specific detailed issues.

IMPLEMENTATION OF TECHNOLOGY TRANSFER

After application-specific details and requirements are determined through the interaction process, the implementation effort is divided into two general categories. In the first category, the provision of the SP-100 technology data base together with contacts to hardware contractors is sufficient to accomplish the technology transfer. As of July, 1994, a number of companies have begun using technologies developed under the SP-100 Program. 'l'he self-Lubricating bearing is an example of a component in this category. Uses for these bearings have been found for equipment designed for a space shuttle experiment, vacuum pumps operating in a vacuum chamber, and fail-safe support system for a kinematic flywheel storage device being tested under hard vacuum conditions. The hig,h-temperature coil is being baselined on generators for a More Electric Airplane concept. The process to bond rhenium to niobium metal has found a home in chambers for small thrusters while our hard coating processes are being considered for wear resistant **surfaces to protect machinery, and as a coating to reduce erosion and increase. the lifetime, in watt] jet orifices.**

In the second category, the SP-100 technology must be tailored, or in some cases, further developed to meet application-specific requirements. Early experience indicates that this constitutes the largest category with commensurate potential benefits. In general, the most effective way of developing the technology is to form a twining arrangement between the industrial user and personnel from laboratories and their contractors who have knowledge about the technology. The industrial user must take the lead and define his requirements for this technology. Then, the laboratories and/or their contractors can modify the technology based on their experience.

As a direct result of early interactions, a number of cooperative teaming arrangements are being formed to transfer technologies, including the gas separator, compliant pad, the Johnson noise thermometer, bonding of ceramics to metals, carbon-carbon tubes, and self-lubricating bearings. We presently are working with a number of companies, both large and small, in developing programs to modify these components for other applications. A small company servicing the soft drink industry has found a novel way to process the liquid syrup through the use of the gas separator. Several companies have proposed the. use of the compliant pad for transporting either heat or electricity through a conductor connection in ceramic parts. The pad prevents the connected ceramic parts from being structurally damaged. The Johnson Noise thermometer is being considered by at least one industrial company for measuring, the temperat ure of jet engines operat ing at temperatures in excess of 3000° F, while our processes to bond ceramics or graphite to metals arc being considered for optical assemblies, turbine wheels, fed-through for an x-ray accelerator, and fabricating the internal structure for large energy storage capacitors.

A number of companies want to modify our basic self-lubricating ball bearing design to allow operation at high temperat urc in a gas environment, or to enable the bearings to either conduct electricity or to **be** cleaned at **high** temperatures. Finally, our carbon-carbon structure is being considered by industry for fabricating various forms of heat exchangers for a variety of commercial applications.

CONCLUSIONS

The conclusions drawn from early activities are:

1) Broad opportunities exist for transferring SP- 100 technologies to a wide range of industrial and commercial ent i t i es.

2) SP- 100 technologies must be tailored to meet the specific requirements of each commercial or industrial entity's application.

3) Teaming arrangements are needed to tailor SP- 100 technologies, where the arrangement links an industrial or commercial entity which knows the market and its requirements with a national laboratory and the component developer who can quickly and cost effectively modify the S}>- 100 technology to meet the commercial requirements.

4) Exploration of technology transfer opportunities requires a proactive effort encompassing: 1) ident ification of technologies having commercial potential; 2) distribution of information; 3) delineation of specific applications and their associated requirements; and, 4) transfer of technology either by providing a data base or mom generally forming teaming arrangements to tailor the technology.

Acknowledgements

The work reported herein was performed by the SP-1 00 Project Office., Jet Propulsion Laboratory, under contract with the U. S. Department of Energy, Oakland Operations Office. The authors wish to acknowledge the support and assistance provided by the NASA Regional Technology Transfer Centers, tbe Commercial Program Office. at the Jet Propulsion Laboratory, and a team of SP- 100 contractors.

References

1. Mondt, J. F., Truscello, V. C., and Marriott, A. T., "SP-100 *Power Program*", Eleventh Symposium, Space Nuclear Power Systems, Albuquerque, NM, 1-94.

2. Marriott, A. T. and Fujita, "1'., *"Evolution of S1'-100 System Designs"*, Eleventh Symposium, Space Nuclear Power Systems, Albuquerque., NM, 1 -94.

3. DeMuth, S. F., "sP-loo *Reactor Subsystem Development* ", Eleventh Symposium, Space Nuclear Power Systems, Albuquerque, NM, 1-94.

4. DeMuth, S. F., *"SP-1 00 Control Drive Assembly Development Plan"*, Eleventh Symposium, Space Nuclear Power Systems, Albuquerque, NM, 1-94.

5. Buksa, J. J. (1994), *"S1'-100 Heat Transport Technology Development"*, Eleventh Symposium, Space Nuclear Power Systems, Albuquerque, Nh4, 1-94.

6. England, C. and Ewell, R. C. (1994), *"Progress on the SP-100 Power Conversion Subsystem"*, Eleventh Symposium, Space Nuclear Power Systems, Albuquerque, NM, 1-94.

TABLE 1. SP-100 PROCESS-ORIENTED TECHNOLOGIES HAVING COMMERCIAL POTENTIAL

PROCESS TECHNOLOGY	COMMERCIAL POSSIBILITIES
Bonding of Rhenium to Niobium	Application of corrosion resistant metal liners to a substrate such as a rocket motor. Techniques applicable to bonding other materials with different coefficients of thermal expansion.
Bonding Metals to Sapphire (Alumina)	Bonding clear insulators to metals in lamps, lasers, special-purpose windows, and high-voltage isolation devices. Techniques for bonding are applicable to amorphous glasses as well as single-crystal oxides,
Bonding Refractory Metals to Graphite	Applications include prosthetic devices, rocket motors, lightweight aircraft components, and brakes. Basic techniques are applicable to bonding of commercial alloys.
Explosively Formed Copper Plate with Niobium Clad	Uses encompass multi-layered structures requiring mechanical bonding of dissimilar metals. Techniques are applicable to metals having different coefficients of expansion.
Hard Surface Coatings on Substrates	Applying surface coatings to substrates to provide wear resistance to sliding surfaces in machinery as well as erosion protection for surfaces exposed to gas and liquid flows.

I ABLE 2. SP-100 DEVICE TECHNOLOGIES HAVING COMMERCIAL POTENTIAL

DEVICE TECHNOLOGY	COMMERCIAL POSSIBILITIES
Compact Heat Exchanger	Very small flat plate liquid-to-gas heat exchangers or any flat plate heat exchanger for transferring heat from a very corrosive fluid to a gas. Fabrication processes accommodate materials such as stainless steel, copper, aluminum, as well as refractory materials,
Conductively Coupled Thermoelectric Converter	Generation of electrical energy by using waste heat from industrial and home furnaces. The thermoelectric converter array would be incorporated into the thermal insulation of the furnaces.
Gas Separator	Replacement of current liquid-gas separators with moving parts that are used **in micro-gravity, e.g., water-air separators used** for environmental control on the space station. Compact liquid-gas separators for ground applications, e.g., removal of gases from aerated water.
High Temperature Linear Position Sensors	Use of Linear Variable Differential Transformers (LVDTS) and positions switches in high-temperature locations for improved control of industrial processes.
High Temperature Motor-Clutch-Brake Assemblies	Industrial applications having radiation or high-temperature environments that require motor-clutch-brake units for actuation of process equipment,
Johnson Noise Thermometer	Measurement of temperatures in furnaces and in radiation environments without encountering the recalibrating effects of temperature or radiation-induced changes in the temperature-sensing element,
Liquid Metal Heat Pipe for High-Temperature Operation	Spread heat uniformly over a heat transfer surface via an array of pipes to enhance waste rejection or transfer of heat to another medium. Also, the pipes can transport concentrated heat from one location to another with only a small temperature drop,
Self-Powered TEM Pump	The thermoelectric-electromagnetic (TEM) pump is able to pump electrically conducting fluids (e.g., liquid metals) at high temperatures, The avoidance of moving parts improves reliability when incorporated in industrial processes.

TABLE 3. SP-1OO COMPONENT TECHNOLOGIES HAVING COMMERCIAL POTENTIAL

COMPONENT TECHNOLOGY	COMMERCIAL POSSIBILITIES
Carbon-Carbon Tubes with Integral Fins and Liners	Tubular heat exchangers for applications such as gas or oil-fired furnaces, Low weight and high strength favor heat exchanger applications on mobile systems,
Complaint Pad	Joining surfaces of materials having different coefficients of thermal expansion, while providing good thermal conduction and electrical transmission. For example, the pad could be used to join a ceramic superconducting cable with a conventional cable,
High Temperature Coils	High temperature devices that use electromagnetic coils and conductors. These devices include motors, position **sensors, solenoid valves, and switches.**
Pressure Transducer Adaptations for Hostile Environment	Industrial and scientific research applications requiring measurement of pressure drops in either fluids at high temperatures exceeding transducer limits or fluids requiring special containment materials.
Self-Lubricating Ball Bearings	Equipment involving rotary motion that operate at high temperatures **in either a vacuum or gas environment. The need** for a separate lubrication system is eliminated.
Very High Temperature Electrical Insulator	**Industrial applications requiring insulator technology to isolate high-voltage environments at high temperatures while maintaining excellent thermal contact,**